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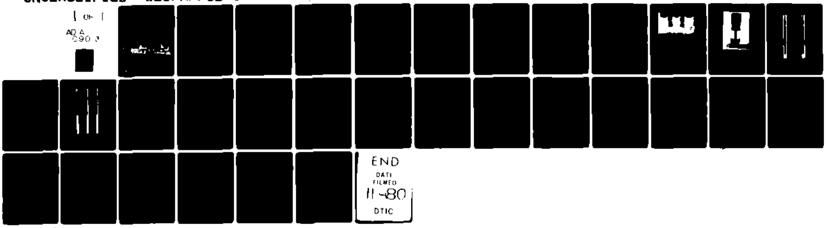

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MULTIPLE-PORT PIEZOMETER INSTALLATION AT ROCKY MOUNTAIN ARSENAL

by

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Final Report

Prepared for Rocky Mountain Arsenal
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and
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This report documents the installation of multiple-port piezometer casing in two borings at the Rocky Mountain Arsenal (RMA) in Denver, Colo. The purposes of the installation were to determine the feasibility of monitoring and sampling groundwater at multiple levels in a single borehole, to compare the installation costs of this type system to the costs of installing open system observation wells, and to compare the chemical analysis data on groundwater samples obtained through the system to the chemical data on groundwater samples obtained through adjacent open system observation wells that (Continued)

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20. ABSTRACT (Continued)

are currently being used at RMA.

The report describes the component parts of the system installed at RMA along with the installation procedure. A cost comparison between the multiple-port system and the observation well system is made and formulas are presented that can be used to compute the installation costs of both the multiple-port system and the observation well system for varying numbers and depths of ports. A limited number of groundwater samples taken through the system precluded a meaningful comparison of the chemical analysis data between groundwater samples obtained through the multiple-port system and those obtained through the adjacent observation well system. The piezometric pressure readings obtained from both systems compared very favorably.

Generally, in situations requiring few ports at shallow depths, an observation well system or cluster is more economical than the single borehole multiple-port system. In situations involving numerous ports at deep monitoring locations, the multiple-port system would be more economical.

Preface

Multiple-port piezometer casing was installed in two borings at the Rocky Mountain Arsenal (RMA), Denver, Colo., during the period 23 April through 1 May 1979 by personnel of the Geotechnical Laboratory (GL) of the U. S. Army Engineer Waterways Experiment Station (WES) under the Contamination Control Program of the RMA. Funding was authorized by IAO No. 62-79, dated 15 February 1979, and was provided by RMA and the U. S. Army Toxic and Hazardous Materials Agency.

Field installation of the casing was performed by personnel of the Explorations Group of the Engineering Geology and Rock Mechanics Division (EGRMD), GL, under the direct guidance and assistance of Messrs. W. H. Black and J. D. McFarlane of Westbay Instruments Ltd., West Vancouver, B. C., Canada, the designers and developers of the system. These men also instructed personnel of the Environmental Laboratory (EL), WES, in the use of the specialized tools required to obtain water samples and piezometer pressure readings through the system. All field operations involved in obtaining water samples and piezometric pressure readings were performed by EL personnel. The chemical analysis on the water samples was performed in a chemical analysis laboratory at RMA. Photographs for Figures 1 through 5 were furnished by Westbay Instruments Ltd.

This report was prepared by Mr. Mark A. Vispi of the Explorations Group, EGRMD, under the direct supervision of Mr. J. L. Gatz, Chief, Explorations Group, and under the guidance of Dr. D. C. Banks, Chief, EGRMD. Mr. J. P. Sale was Chief of GL during the field work. Dr. Banks was Acting Chief of GL during the writing and publication of this report.

Directors of WES during the field work and the writing and publication of this report were COL John L. Cannon, CE, and COL Nelson P. Conover, CE. Technical Director was Mr. F. R. Brown.

Contents

Conversion Factors, Inch-Pound to Metric (SI) Units of Measurement

Inch-pound units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	2.54	centimetres
pounds (force) per square inch	6.894757	kilopascals
gallons (U. S. liquid)	3.785412	litres

MULTIPLE-PORT PIEZOMETER INSTALLATION AT ROCKY MOUNTAIN ARSENAL

Introduction

1. Multiple-port piezometer casing was installed in two borings at the Rocky Mountain Arsenal (RMA) during the period 23 April through 1 May 1979. The purposes of the installation were to determine the feasibility of monitoring and sampling groundwater at multiple levels in a single borehole, to compare the installation costs of this system with the costs of installing open system observation wells, and to compare the chemical analysis data on groundwater samples obtained through this system to the chemical data on groundwater samples obtained through the open system observation wells that are currently being used at RMA.

Description of the System

2. The multiple-port casing or MP system was designed and developed and is distributed by Westbay Instruments Ltd., West Vancouver, B. C., Canada; in the United States the system is distributed by the Slope Indicator Company, Seattle, Wash.

3. The MP system uses 1-1/2-in.-ID* plastic pipe sections with specially machined ends to accept special couplings. The system allows a number of water pressure measurements (through piezometer port couplings) and water samples (through either piezometer or pumping port couplings) to be obtained at different elevations in a single borehole. Piezometer and pumping port couplings can be installed at required depths or at intervals as close as 5.0 ft. Piezometric pressure readings are obtained through piezometer port couplings with a specially designed pneumatic probe which transmits the pressure data, through a pneumatic

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* A table of factors for converting inch-pound units of measurement to metric (SI) units is presented on page 3.

tube, to a surface readout unit. An electric probe is also available that reads the piezometric pressures electrically and transmits the data to a surface readout unit in digital form. Water samples are taken and well development can be accomplished through pumping port couplings using specially designed tools. All probes and tools are available from Westbay Instruments on either rental or purchase basis.

Couplings used in the system

4. The couplings use "O"-rings to provide a positive seal between them and the casing sections. A shear wire threaded in a groove common to the coupling and the casing holds the parts together as shown in Figure 1. The casing is available in 1-, 2-, 5-, and 10-ft lengths. These lengths will normally provide a combination whereby any depth stratum or aquifer can be monitored. The piezometer port and pumping port couplings have the same physical dimensions as the regular or blank couplings and are substituted for the regular couplings at the depths that they are required.

5. The pumping port coupling consists of a screened inlet through which rather large volume water samples can be obtained and formation development performed. The port can be opened or closed by moving an "O"-ring-sealed sleeve that isolates the port from the inside of the casing. This sleeve is moved from inside the casing using a specially designed tool. Figure 2 shows a pumping port coupling.

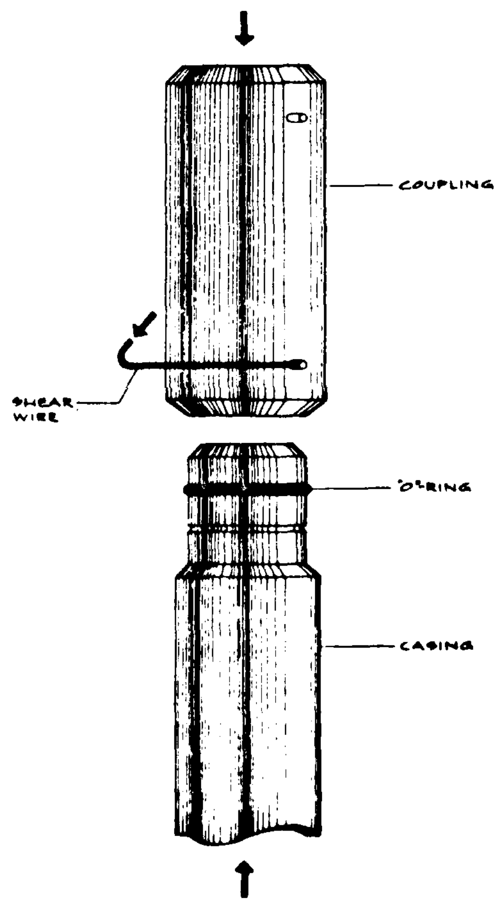


Figure 1. Coupling connection system (courtesy Westbay Instruments Ltd.)

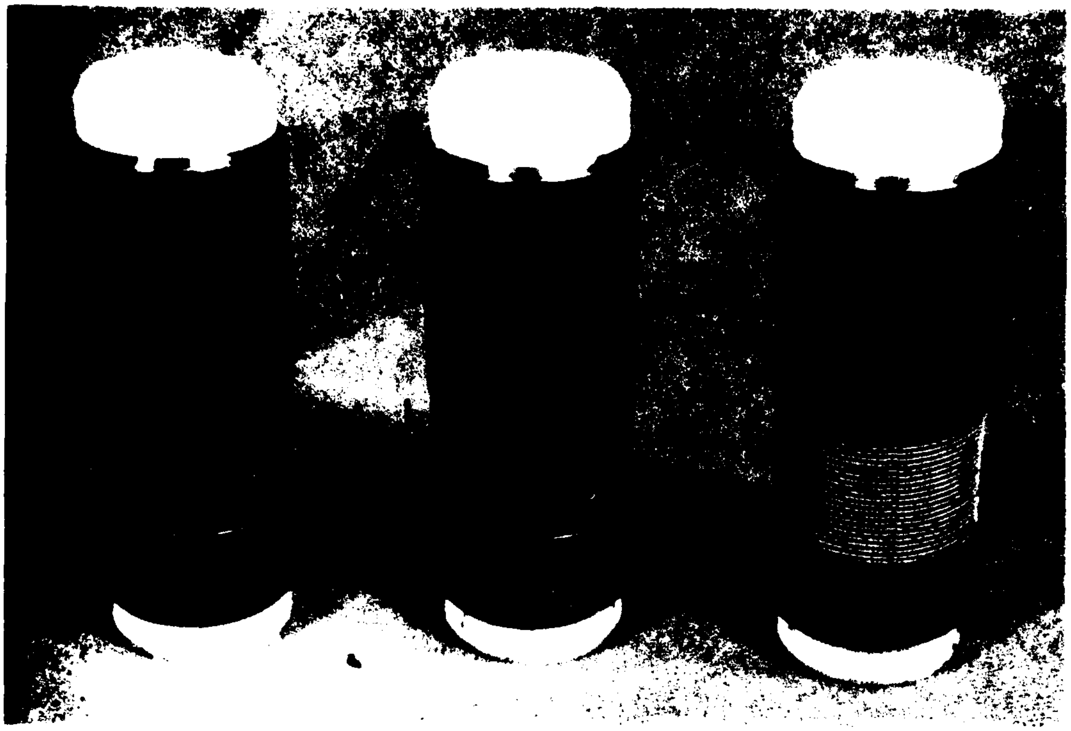


Figure 2. Pumping port coupling. The interior sliding valve in a pumping port coupling is sealed by "O"-rings and is operated by a downhole tool. The interior valve is open in (a) and closed in (b). The screen that is normally placed on the exterior is shown in (c). It is removed in (a) and (b). (Courtesy Westbay Instruments Ltd.)

6. A retrievable packer can be installed below a pumping port and the port opened to allow groundwater to rise in the casing to a level consistent with the piezometric head existing at the depth of the pumping port. Used in this manner, the system can serve as an open-type observation well. When used in this fashion, only one port of the multiple-port system should be opened.

7. The piezometer port coupling consists of a filter cloth-wrapped inlet that is sealed from the inside of the casing by a spring-loaded stainless steel ball valve. Figure 3 shows the inlet portion of the coupling. To read or obtain piezometric pressures through this port, a special probe is lowered, inside the casing, to the elevation of the port. A special aligning spiral that is molded in the inside of the

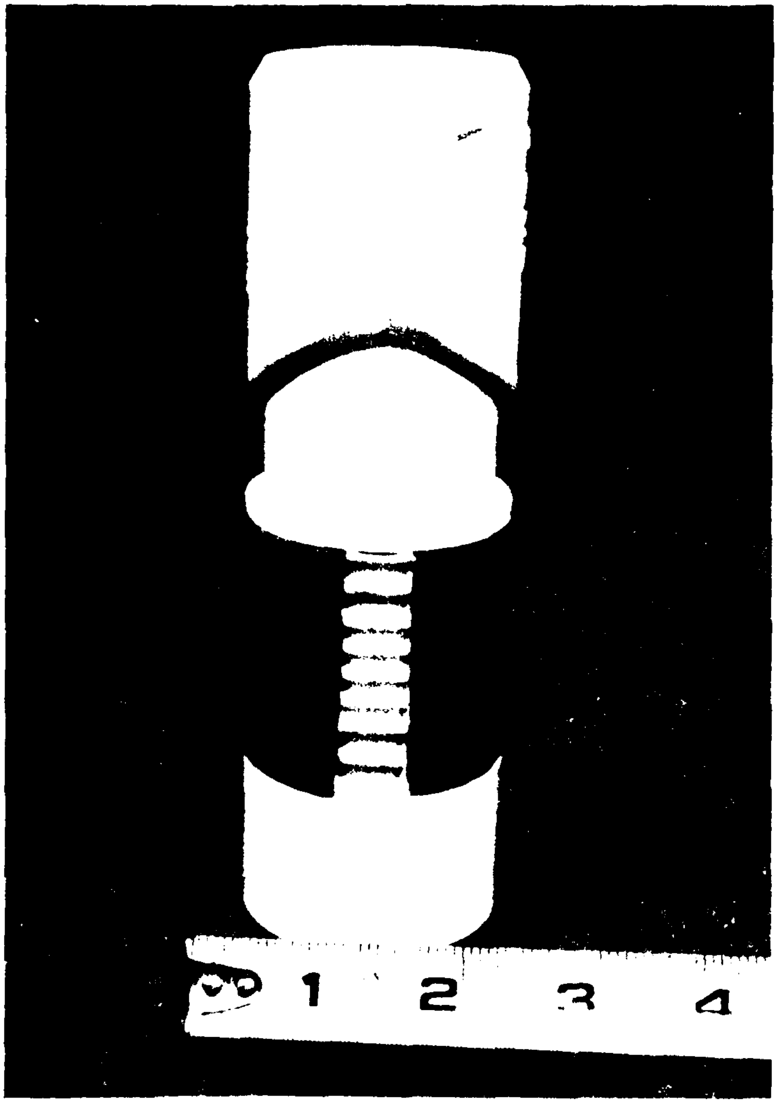
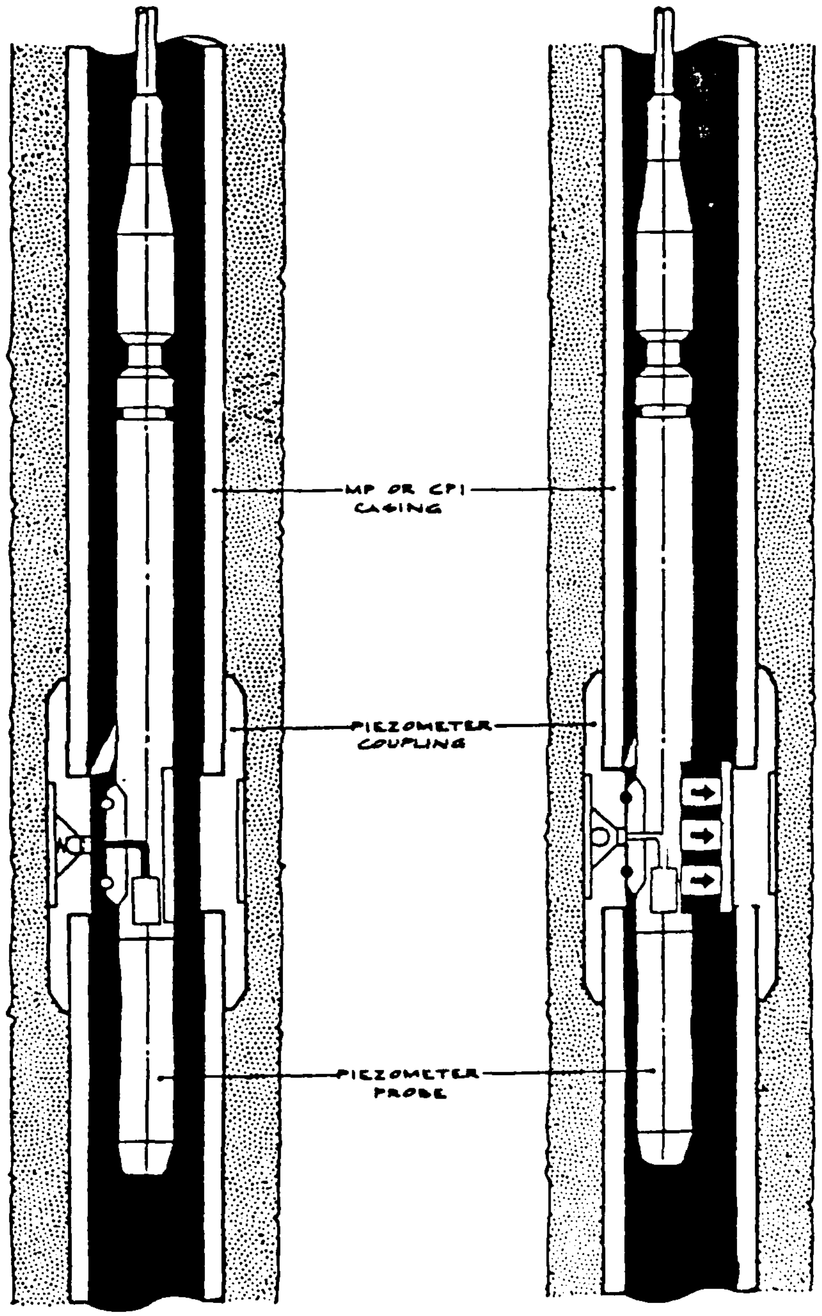


Figure 3. Piezometer port coupling
(courtesy Westbay Instruments Ltd.)

coupling aligns the tool with the ball valve. Air pressure from the surface is used to force the tool against the ball valve, thereby opening the valve and also sealing the port against the tool. The piezometric pressure at the port can then be monitored on a surface readout unit. Figure 4 shows the operation of the piezometer probe. The piezometer



a. Probe is located at a port

b. Pneumatic activation of the probe seals and then opens the port. Pressure is displayed on the surface

Figure 4. Piezometer probe operation (courtesy Westbay Instruments Ltd.)

ports can also be used to obtain small volume water samples by using another specially designed sampler probe as shown in Figure 5.

8. Usually, the pumping ports and the piezometer ports are used in conjunction with each other and can be spaced as close as 14.0 in. in the aquifer being monitored. The pumping port, which is normally placed below the piezometer port, is used to remove the contaminants caused by drilling, to develop the aquifer surrounding the ports, and to obtain large volume water samples. The piezometer port is used to monitor piezometric pressures and to obtain small volume water samples.

Borehole seals used in the system

9. Sealing the borehole between ports can be accomplished by several methods. Sand packs can be placed around the piezometer and pumping ports and bentonite seals (either bentonite pellets or a bentonite-cement grout mixture) used to seal the boring between ports thereby isolating the individual ports. This method can also be used in a cased boring. The casing is removed as the sand packs and bentonite seals are placed.

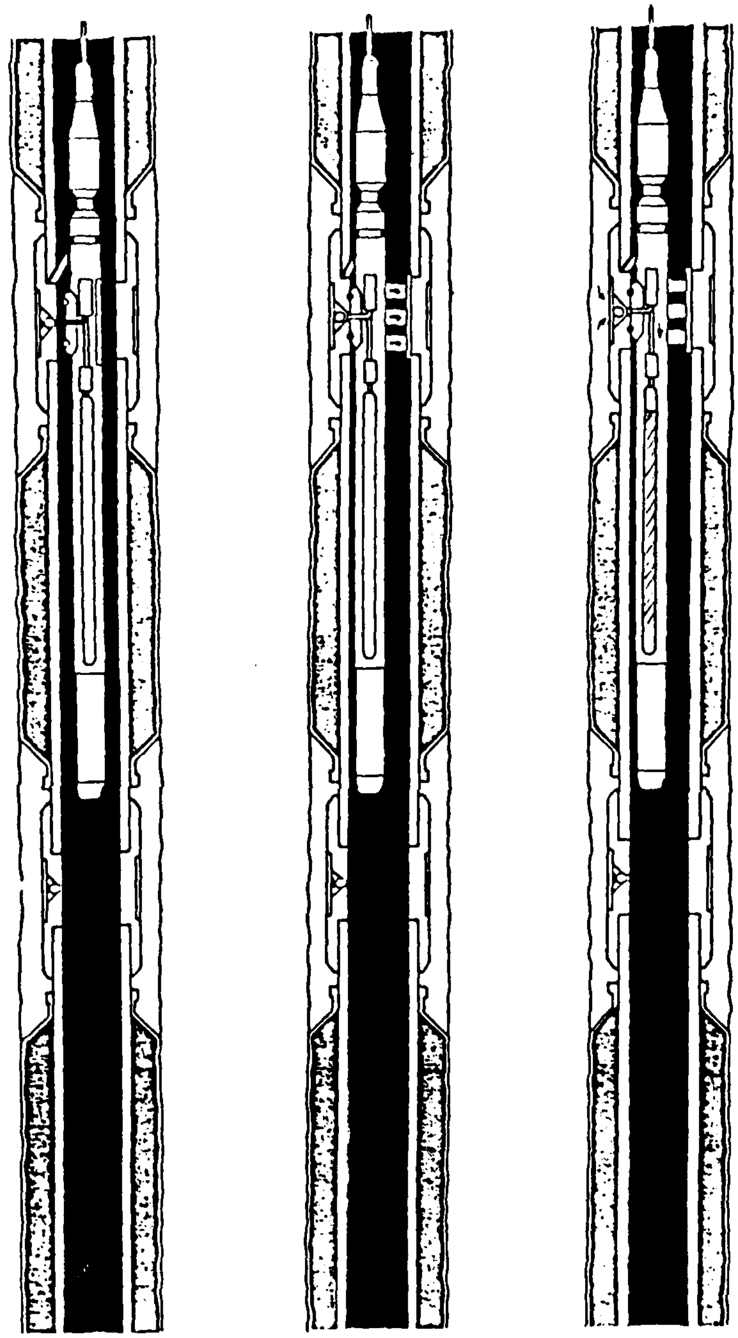
10. A permanent packer arrangement can also be used to seal between ports. These packers, which are installed above and below the ports, are constructed of an expandable plastic material and mounted on a standard 5.0-ft length of MP casing. They can be inflated with a special tool from inside the casing with air, water, or a cement grout.

11. The packers are designed for use in boreholes in materials whose side walls are sufficiently strong to support the pressure exerted by the expanded packer, such as in rock. The packers can be used in boreholes where flowing or artesian water exists and where the boring side walls are subject to caving. They can be set through 3.0-in.-ID casing and can be inflated as the casing is removed.

The Rocky Mountain Arsenal Installation

Installation

12. The MP system was installed at RMA in two, 111.5-ft-deep boreholes (801-B and 801-P) located as shown in Figure 6. The two borings



a. Probe locates port

b. Pneumatic activation of probe seals then opens port

c. Single sample is collected

Figure 5. Pneumatic fluid/gas sampler probe operation (courtesy Westbay Instruments Ltd.)

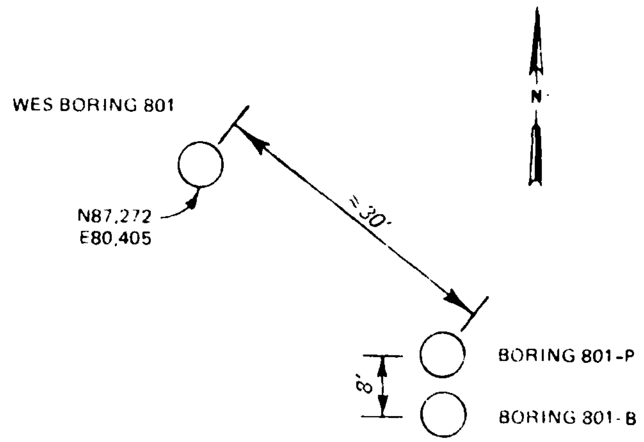


Figure 6. Boring locations

are near U. S. Army Engineer Waterways Experiment Station (WES) boring 801 and are located in Section 26. The coordinates of boring 801 are North 87,272 and East 80,405. In boring 801-P, the system was installed using permanent packers located above and below a set of ports. In this case, the packers were inflated with water. A total of six piezometer and pumping port combinations were installed in this boring. Figure 7 shows the "as constructed" details of the system installed in boring 801-P. The method of installation consisted of setting 34.0 ft of 5-3/4-in.-ID flush joint steel casing through the upper alluvium. A 3.0-in.-diam tricone roller bit was then used with clear water as the drill fluid to advance the boring to a depth of 111.5 ft. Sand was placed around the topmost piezometer and pumping ports and a bentonite-cement grout seal placed from the top of the sand pack to the surface prior to removing the steel casing.

13. The piezometer and pumping ports were installed at the same depths in 801-B as in 801-P. In boring 801-B, sand was placed around the ports and bentonite pellets used to seal between ports. Figure 8 shows the "as constructed" details of the system installed in boring 801-B. In this boring, 34.0 ft of 5-3/4-in.-ID flush joint steel casing was set through the upper alluvium. A 5-5/8-in.-diam tricone roller bit

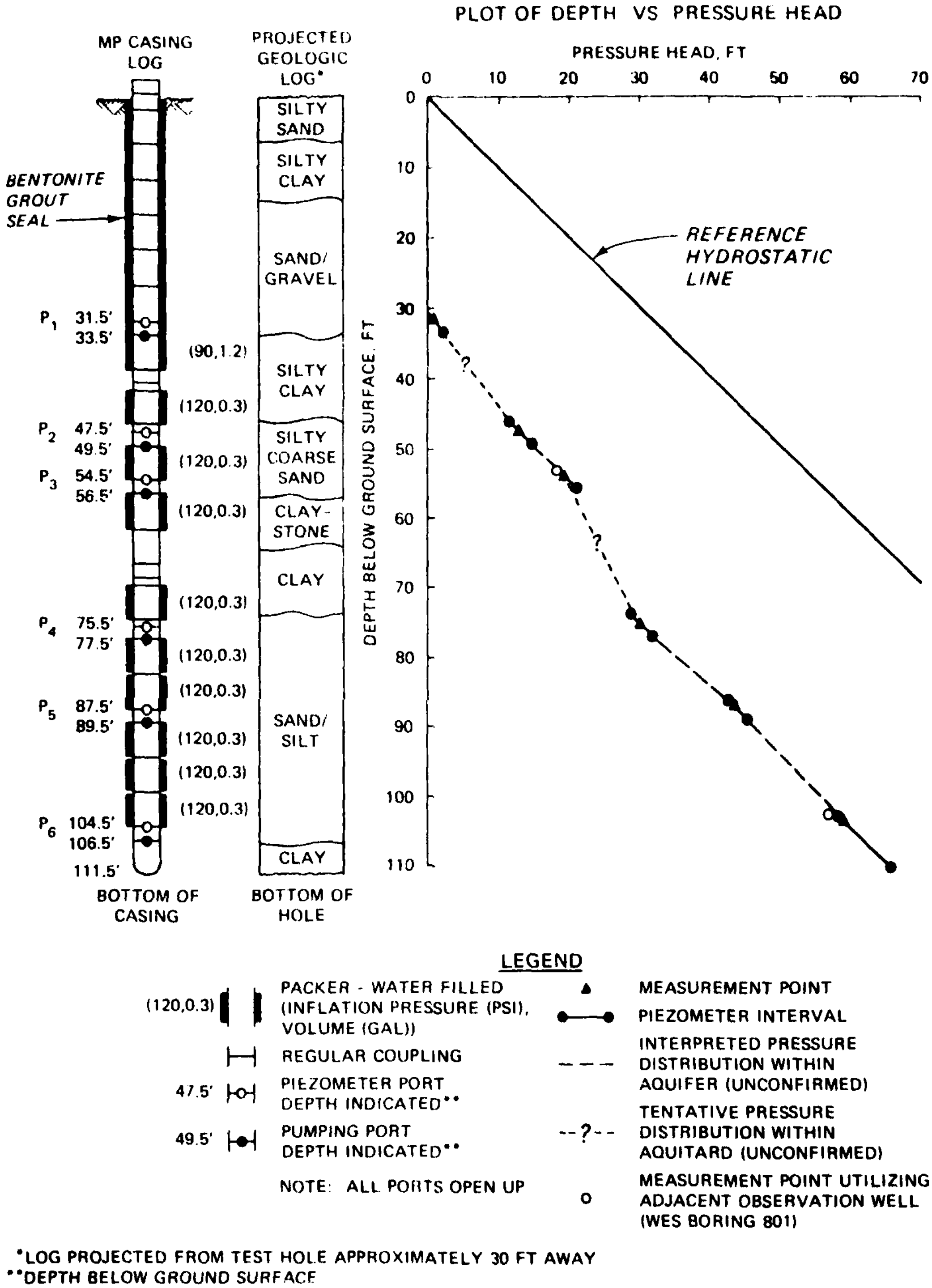


Figure 7. Details of boring 801-P

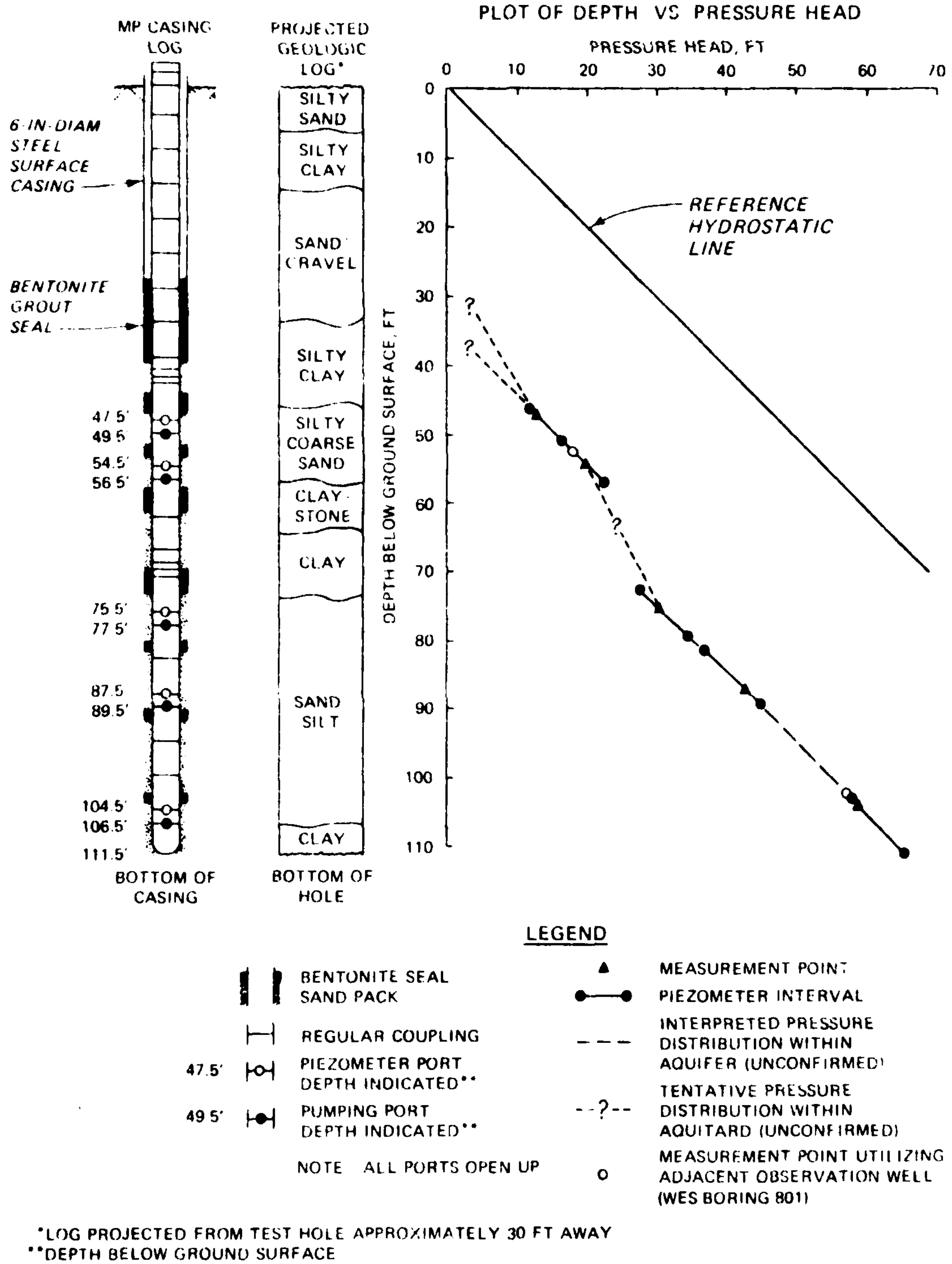


Figure 8. Details of boring 801-B

was then used with clear water as the drill fluid to advance the boring to a depth of 111.5 ft.

14. The bentonite pellets bridged in the steel casing of boring 801-B as the pellets were being placed for the seal above the topmost set of ports (31.5 and 33.5 ft). Attempts were made to remove the bridged pellets, and it was assumed the bridge had been successfully removed. However, when the steel casing was pulled, the MP casing separated at the bottom of the pumping port coupling at a depth of 33.5 ft. The coupling was recovered intact, but it is not known whether the shear wire failed or simply was not installed. Evidently, the bentonite bridge that formed in the steel casing was not completely removed and provided enough gripping force on the MP casing to separate it. The separated portion was reconnected; however, the piezometer and pumping ports that were to be located at 31.5 and 33.5 ft, respectively, could not be installed. The lower five sets of ports are operational.

Operation

15. The special tools required to obtain piezometric pressures and water samples were rented from Westbay Instruments for a period of 1 month. Water samples and piezometric pressures were obtained from the system by personnel of the Environmental Laboratory, WES, during the month that the equipment was rented. Because of ongoing work and previous commitments, the field crews obtaining groundwater samples in the numerous observation wells installed at RMA were not able to spend the required time to properly develop the pumping and piezometer ports in the MP system. Because of this, water samples were obtained only once, and consequently little chemical data was obtained from the system.

Groundwater sampling and analysis

16. Samples for chemical analysis were taken approximately 3 weeks after the multilevel samplers were installed. No well development or flushing was conducted prior to sampling. One round of samples was taken using the procedures recommended by Westbay Instruments. For each sample collected, the special sampling tool was lowered to the sampling level desired, the port opened, and water allowed to flow into the tool. The flow rates were very low possibly due to insufficient

head or port plugging. The one workday required to collect the samples for this limited investigation resulted in a much slower sampling rate than that achieved for sample collection through the observation well system at RMA.

17. The samples collected and the analyses conducted in wells 801-B and 801-P and for well 801 (used as a control) are indicated in Table 1. Well 801 consists of a cluster of three piezometers with screen depths as indicated. The shallow piezometer was "dry," and therefore no sample could be collected. Wells 801-B and 801-P were installed with six sampling ports at depths given in Table 1. The top port on the bentonite-sealed casing (801-B) was eliminated, and no sample could be collected. Analyses were limited to chloride and DIMP due to the small volumes of samples collected. In some cases, only a sufficient volume could be collected for chloride analysis, and in other cases the port was essentially "dry."

18. The analytical results as shown in Table 1 are not generally comparable either between wells 801-B and 801-P or among wells 801-B, 801-P, and 801. This incomparability was probably caused by limitations in the conduct of the sampling and analysis investigation. The lack of well development and the short time between well placement and sampling probably did not allow groundwater equilibrium conditions to be reestablished. Reproducibility of the results could not be verified since only one sample was collected from each port. The samples collected from the Westbay wells were probably not representative of the surrounding groundwater associated with each port. For this reason, the analytical data obtained during this investigation could not be used to provide a fair evaluation of the Westbay sampling system.

Piezometric pressures

19. Piezometric pressures were obtained from the piezometer ports in both borings only once during the period that the required tool was rented, and that occurred 4 days after the system was installed. The piezometric pressures obtained are tabulated in Table 2 and presented in graphical form in Figures 7 and 8. The pressures obtained from both borings are essentially identical. However, the plots in Figures 7

Table 1

Chemical Data Obtained During the Westbay Study

	Well 801			Westbay Wells					
				Well 801-P Mechanical Seal			Well 801-B Bentonite Seal		
Relative Sample No.	Screen Depth ft	Chloride Conc mg/ℓ	DIMP Conc µg/ℓ	Sampling Port Depth ft	Chloride Conc mg/ℓ	DIMP Conc µg/ℓ	Sampling Port Depth ft	Chloride Conc mg/ℓ	DIMP Conc µg/ℓ
1	25-34	N*	N	31.5	1095	I**	31.5	N	N
2	-	-	-	47.5	37	< 2	47.5	25	I
3	49-57	2460	87.9	54.5	1720	24.2	54.5	34	I
4	-	-	-	75.5	190	< 2	75.5	N	N
5	-	-	-	87.5	39	< 2	87.5	N	N
6	99-107	156	4.2	104.5	53	< 2	104.5	1275	I

* N indicates no sample.
** Indicates insufficient sample.

Table 2

Piezometric Pressure Probe Readings

Depth to Port ft	Boring 801-F Reading, psi	Boring 801-B Reading, psi
31.5	0.2	--
47.5	5.7	5.5
54.5	8.3	8.6
75.5	13.0	13.2
87.5	18.7	18.4
104.5	25.5	25.5

and 8 indicate that the plotted measures do not fall on a straight line. This trend has also been seen in other piezometric measurements. The piezometric information obtained from boring 801 has also been plotted in Figures 7 and 8 and compares very favorably with that obtained from borings 801-B and 801-P.

Cost of the System

20. The cost of the MP system is quite high. Costs of materials at the time of installation are listed in Table 3. These costs have since increased. Also, the special tools that have to be used with the system and are required to inflate packers, obtain piezometric pressures, open and close the pumping ports, and obtain water samples are quite elaborate and are quite expensive to rent or lease. Table 3 also lists the rental rates of the tools required for the RMA project. The tools are also available for purchase, but the purchase price is not known.

21. Because of the many variables involved, it is quite difficult to make an accurate cost comparison between the MP system and open-type observation wells. A generalized cost comparison was made using the following assumptions:

- a. Ten feet of 2-in.-slotted PVC screen and 2-in. PVC pipe riser are used for the observation wells.
- b. A separate boring is drilled for each observation well.
- c. The material and labor costs are 1979 rates.
- d. No casing or drilling fluid additives are required to stabilize the boring side walls during installation.
- e. The individual ports of the MP system are sandpacked and sealed using bentonite pellets rather than inflatable packers. All cost and time data shown in the accompanying plots were determined from actual installation of the systems at RMA. Only the actual material and labor costs were used in calculating the installation costs of the two systems. The rental costs of the sampling and pressure readout probes used with the MP system are not included.

22. Figure 9 shows a plot of cost versus depth for a single

Table 3

Multiple-Port System Material Costs and Tool Rental Rates

Material Costs (1979)	
Casing - 5 ft-lengths	$ 2.65/ft
2 ft-lengths	4.40/ft
1 ft-length	5.00/ft
Packers	101.20 each
Piezometer Port Couplings	52.40 each
Pumping Port Couplings	185.00 each
Regular (plain) Couplings	7.30 each
Tool Rental Rates (1979)	
Pneumatic Pressure Probe w/readout	494.00/mo
Water Sampling Tool w/cable and reel (used in piezometer ports)	1188.00/mo
Open/Close Tool for pumping port operation	247.00/mo
Bailer and Retrievable Packer System (used in conjunction with the pumping ports)	882.00/mo
Packer Inflation Tool (including inflation pump and hose)	186.00/day

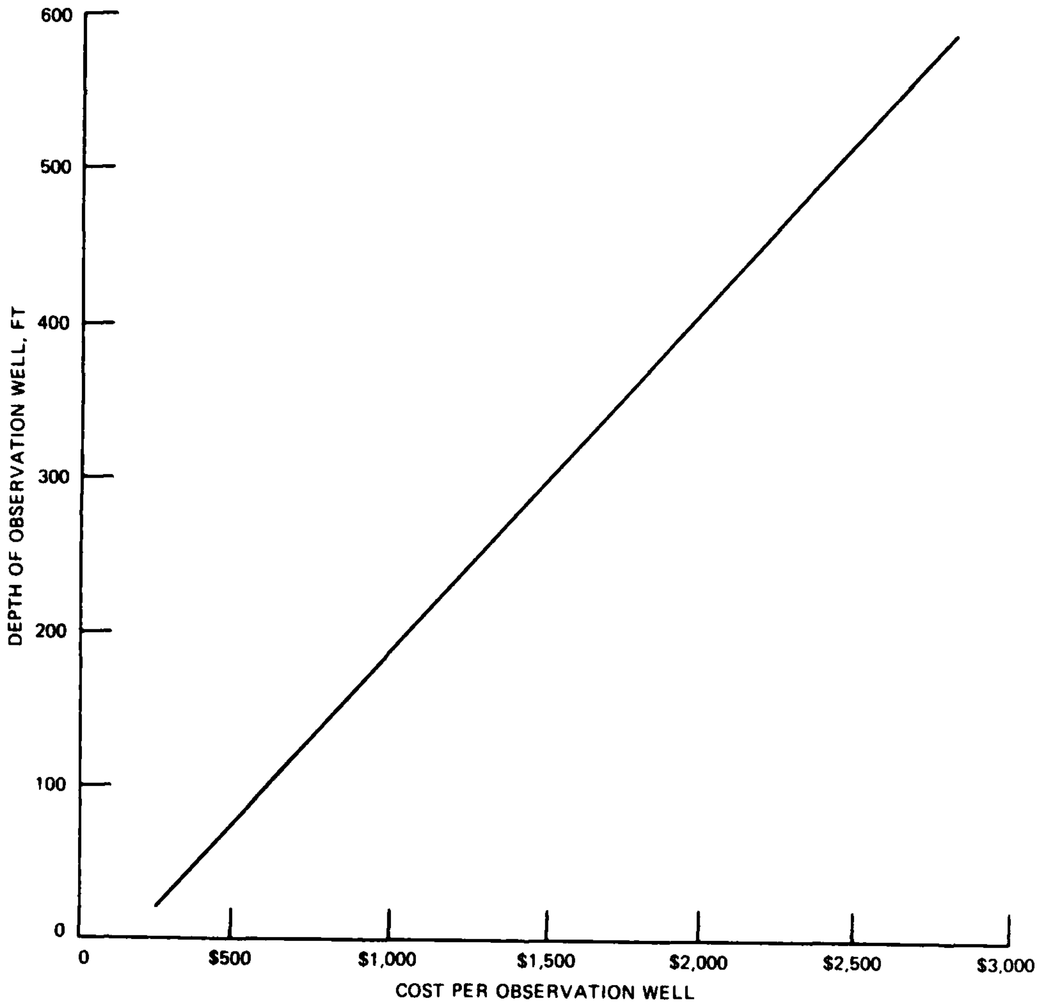


Figure 9. Single observation well installation costs

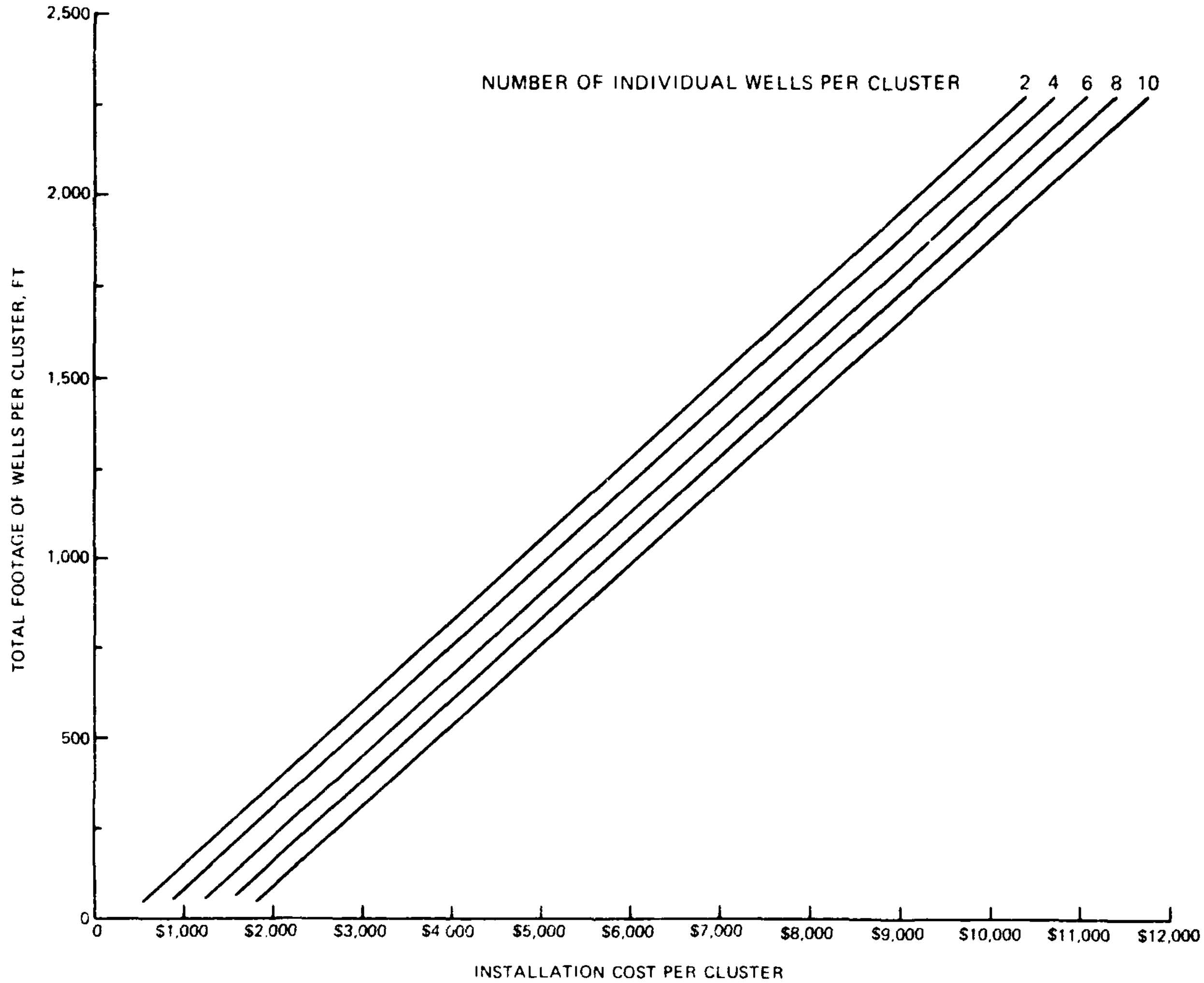


Figure 10. Installation costs for an observation well cluster

observation well. Figure 10 shows a plot of total footage of observation wells per cluster versus the installation cost per cluster for varying numbers of wells per cluster (2, 4, 6, 8, and 10 wells).

23. A plot that can be used for determining the installation costs of an MP system is presented in Figure 11. The depth of the deepest port is plotted versus installation costs for varying numbers of ports in the system (2, 4, 6, 8, and 10 ports).

24. Once the number and the depth of aquifers that are to be monitored are determined, the total footage of observation wells can be calculated and installation costs determined by using the plot in Figure 10. Also, the cost of an MP system can be determined by using the plot in Figure 11. When calculating costs for an MP system, the number of aquifers and the depth of the deepest aquifer must be known. The depth of the intermediate aquifers is not critical because the ports used to monitor these aquifers can be placed at any elevation within the borehole.

25. The installation costs of the two systems can also be computed using the following formulas:

a. Installation costs for an observation well cluster:

$$\text{Cost} = \Sigma d(4.5) + N(160) \qquad (1)$$

where:

Σd = total footage of wells per cluster, ft
N = number of individual observation wells
Cost = total cost of installing the cluster of N observation wells, dollars

b. Installation costs for an MP system:

$$\text{Cost} = D(8.1) + N(136) \qquad (2)$$

where:

D = depth of the deepest port in the system
N = number of ports

26. In some situations, installation time may be more critical than installation costs. Figure 12 shows a plot of total footage of observation wells per cluster versus installation time for varying numbers of wells per cluster (2, 4, 6, 8, and 10 wells). The installation time for an MP system is presented in Figure 13.

27. The plot shown in Figure 14 can be used to determine the most

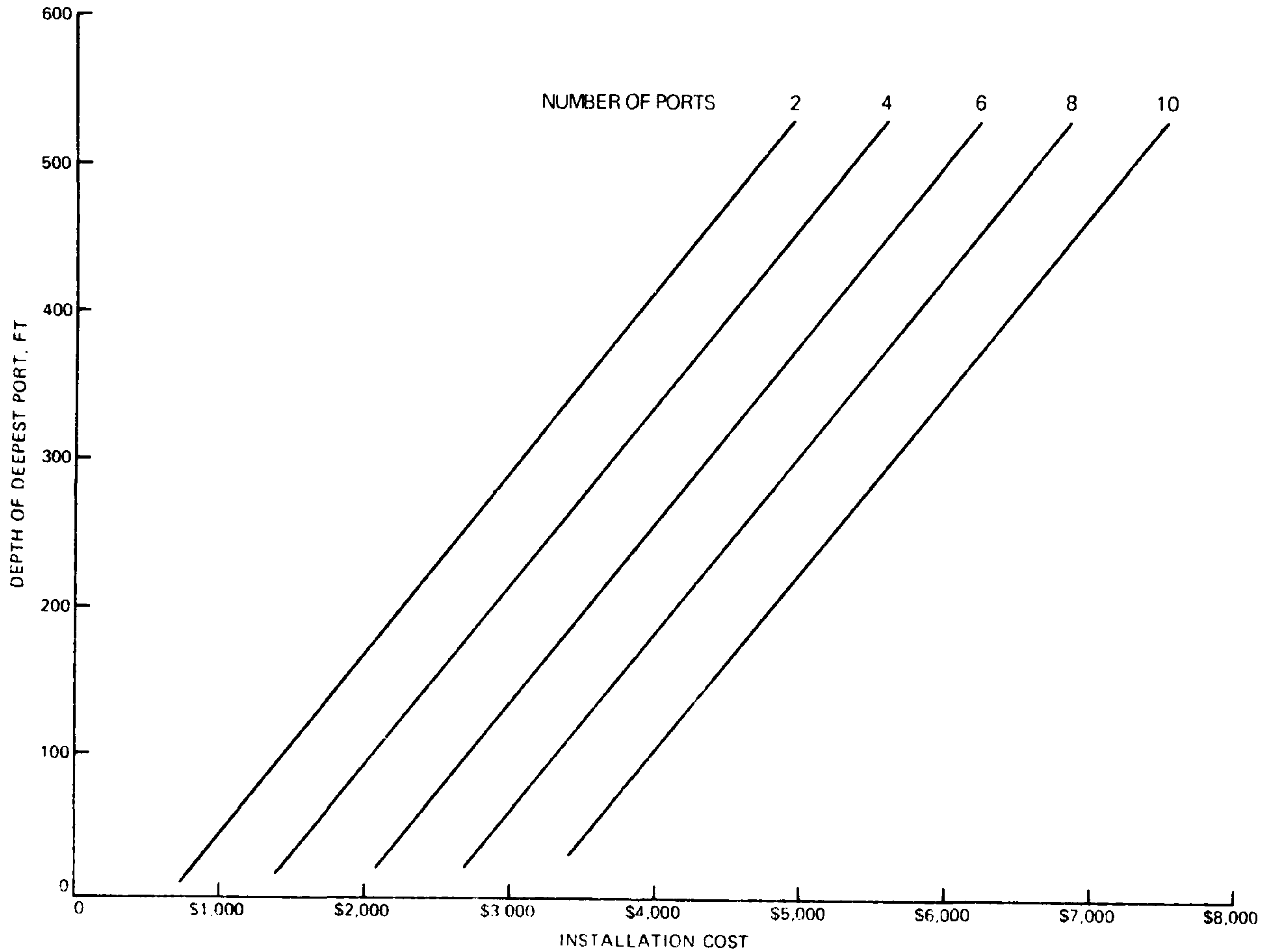


Figure 11. MP system installation costs

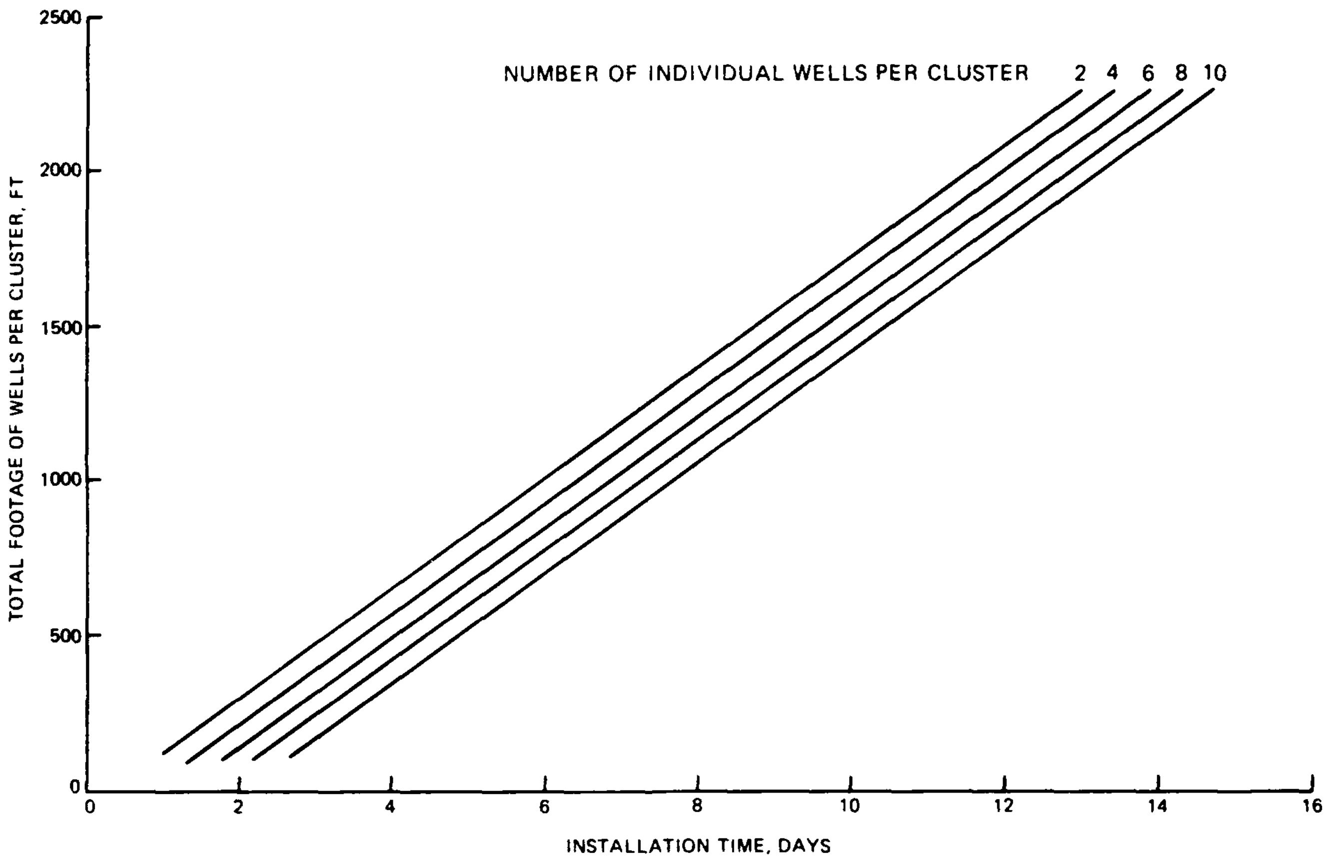


Figure 12. Installation time for an observation well cluster

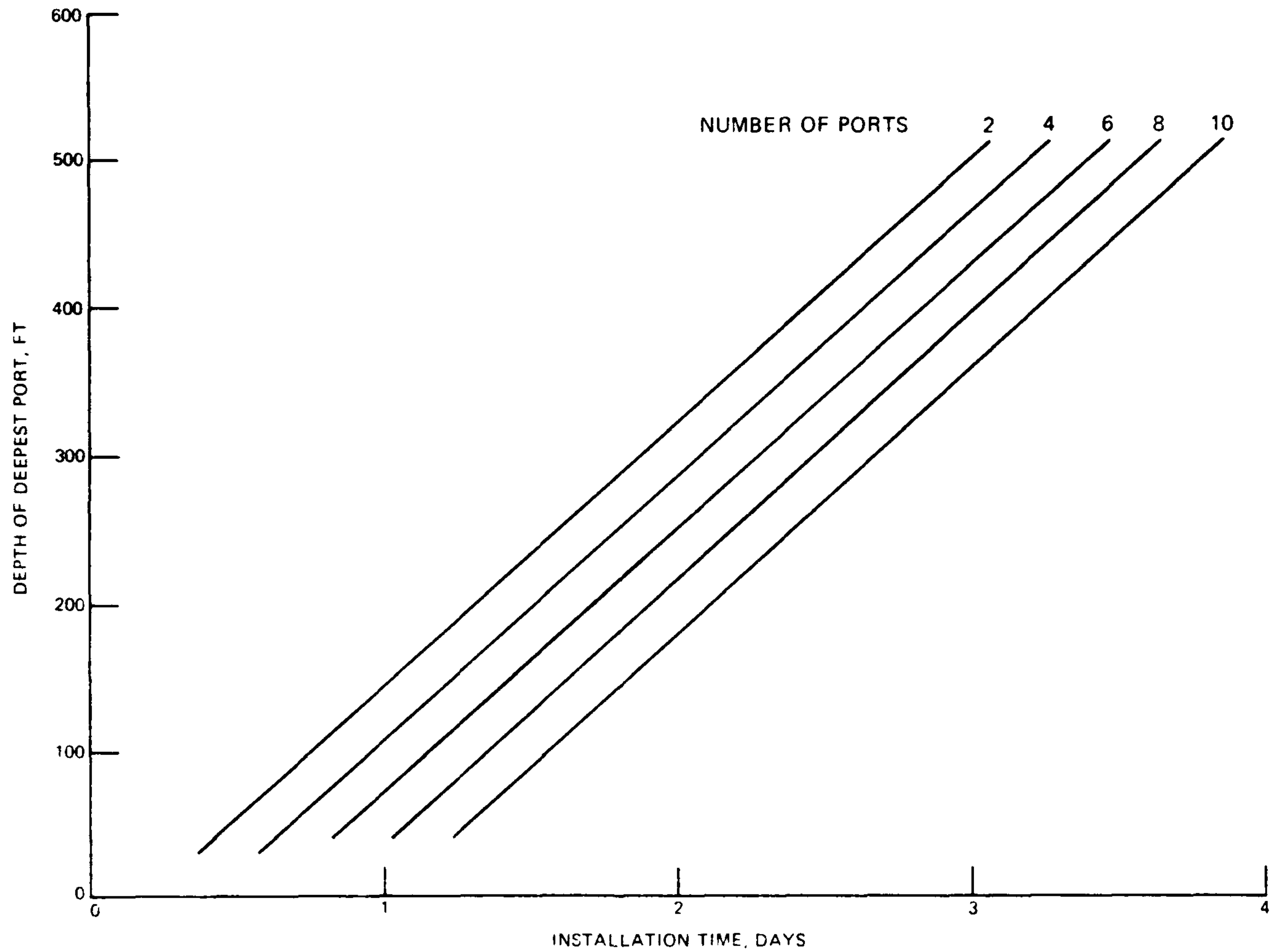


Figure 13. MP system installation time

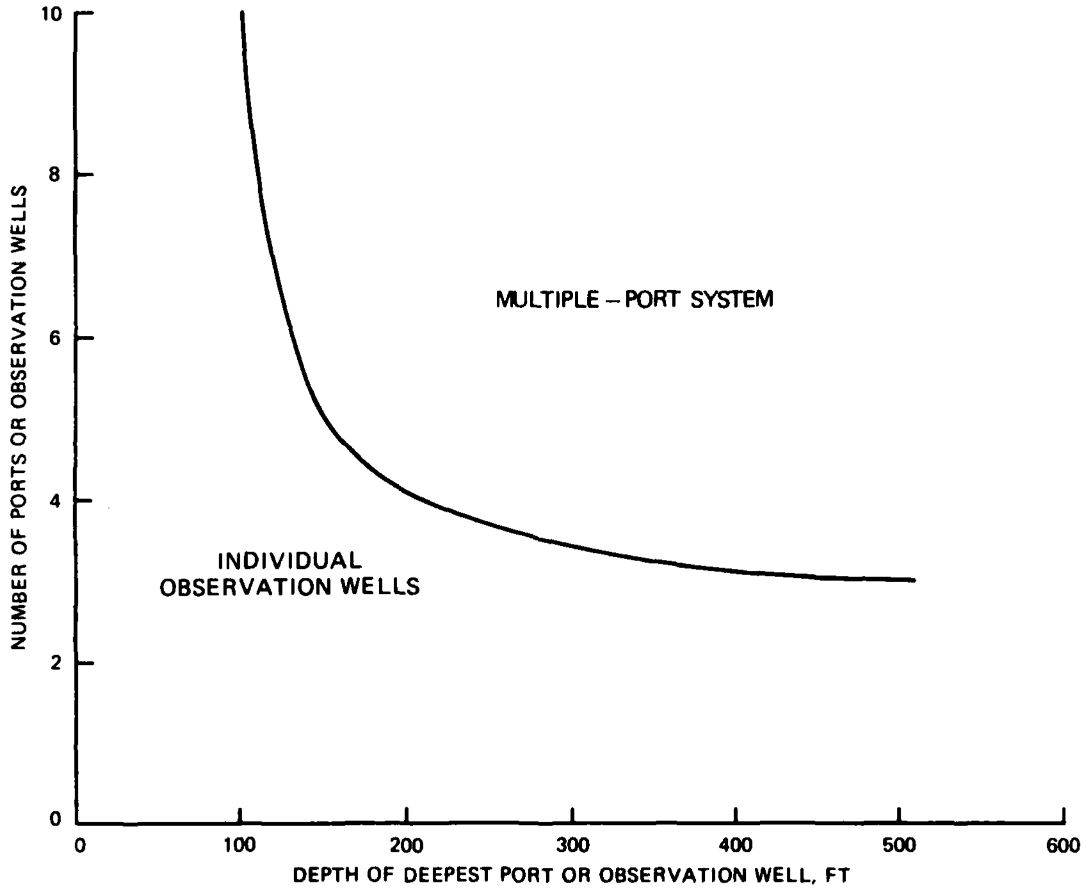


Figure 14. Individual observation wells versus MP system (for evenly spaced wells or ports)

economical system to use in a situation where the individual observation wells or MP ports are equally spaced from the ground surface to the deepest well or port such as might be installed to monitor contaminant stratification in an aquifer. If the number of individual observation wells per cluster or number of ports in the MP system plotted versus the depth of the deepest well or port falls to the left, or below the cutoff line, it is more economical to use observation wells; conversely, if the point falls to the right or above the cutoff line, the MP system would be more economical to install.

Conclusions

28. Because of time and budget constraints, no well development or flushing was performed and only one round of water samples was obtained from the system. This precluded a meaningful comparison of the chemical analysis results of these samples to those obtained through adjacent open system observation wells. An installation cost comparison between the multiple-port system and the open system observation wells can be made and is dependent on the number and depths of aquifers to be monitored. Generally, in situations requiring few ports at shallow depths, an observation well cluster is more economical. In situations involving deep monitoring locations, the multiple-port piezometer system would be more economical especially if sufficient ports are installed to warrant purchasing the necessary sampling and monitoring tools that must be used with the system.

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